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# National Data Buoy Center (NDBC) National Backbone Contributions to the Integrated Ocean Observation System (IOOS)

Richard L. Crout, Don T. Conlee, and Landry J. Bernard  
NOAA National Data Buoy Center  
1100 Balch Blvd.  
Stennis Space Center, MS 39529 USA

**Abstract:** As an integral part of the Integrated Ocean Observation System (IOOS) “National Backbone”, the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) is increasing the oceanographic capabilities of the NDBC Ocean Observing System (NOOS). The goal of the effort, known as Conversion of Weather Buoys (ConWxB), is to increase the number of ocean instruments on existing backbone buoys.

The nascent IOOS regional associations were asked to provide suggestions of existing NDBC buoy locations to add directional wave, current profile, and salinity sensors within their regions. Most regional associations responded and in one case an update was forwarded to NDBC. Using these inputs and the upcoming buoy schedule for the next two years, an initial list of probable buoys was established for each type of sensor. An effort was made to respond to priority areas as provided by the regional associations. The criteria used to establish the ocean sensor suite on buoys and the distribution of sensors vertically within the water column will be discussed.

Under ConWxB, NDBC is deploying ocean sensors on all buoys. Directional waves are derived primarily from the angular rate system (ARS) installed inside the buoys. However, the design of the six meter NOMAD buoy does not respond to ocean movement in a way conducive to provide directional ocean waves from this system. Directional wave sensors will be therefore be deployed on three meter buoys. In addition, NDBC has a long history of supporting the Army Corps of Engineers with high resolution heave, pitch, and roll (HIPPY) sensors, which will continue.

Doppler current profilers will be employed on approximately three dozen three meter and ten meter buoys. The remainder of the NDBC buoys, including six meter NOMAD buoys, will be equipped with near surface current meters. NDBC has gained experience deploying acoustic Doppler current profilers under the Coastal Storms Program and a project associated with the Minerals Management Service

Twelve three meter discus buoys have been selected for conductivity/temperature strings and another thirty buoys will have conductivity/temperature sensors attached to the bridle. These later buoys include the six meter NOMAD and ten and twelve meter discus buoys.

NDBC is deploying a new 1.8 meter discus buoy with directional waves and ADCP sensors, and a new compact meteorology package. These buoys will primarily be associated with NDBC Coastal Marine Automated Network (C-MAN) sites. After a

successful testing stage, NDBC will deploy eleven of the 1.8 meter buoys.

The addition of these ocean assets to the National Backbone for IOOS supports the individual regional associations and the goals of NOAA. The implementation of ConWxB has already begun and should be completed by the end of Fiscal Year 2007. The increased complexity of transmission, processing, and display of real-time oceanographic data at NDBC is also begin addressed through a number of current programs and initiatives.

## I. INTRODUCTION

The conversion of weather buoys (ConWxB) is an effort by NOAA’s National Data Buoy Center (NDBC) to add ocean sensors to many of the current NDBC Ocean Observing System (NOOS) buoys. The funded effort supports the Integrated Ocean Observing System (IOOS), which is part of the United States contribution to the Global Earth Observation System of Systems (GEOSS).

NDBC has established Regional Association Coordinators for the Ocean Observation Network (RACOONs) for each of the eleven Regional Associations (figure 1). The RACOONs act as liaisons to the Regional Associations and interact with them to derive requirements and keep them informed of NDBC activities.

Ocean sensors considered for ConWxB include acoustic Doppler current profilers (ADCPs), conductivity-temperature (CTs) sensors, angular rate system (ARS) sensors, and near surface current meters. At twelve buoys NDBC will deploy CT strings in order to sample the vertical variability of the water column.

## II. METHODS

In a letter to the governing body of each regional association, NDBC requested that a prioritized list of buoys be provided for the addition of directional waves, salinity, and ADCP sensors to present NDBC buoys. In some instances, the regional association also provided requests for additional NDBC buoys in their regions. The list of prioritized buoys was analyzed against the planned visits to each of the NDBC buoys and a list of buoys established for the addition of

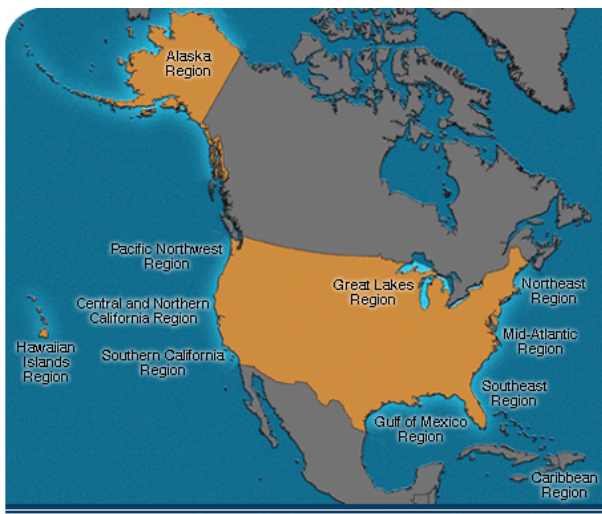


Figure 1. The eleven Regional Associations for IOOS.

ADCP, directional wave, and/or salinity sensors. Planned visits to NDBC buoys are based on a cost-effective maintenance philosophy. Buoys are serviced on a two, three, or four year cycle, depending on power availability and consumption. Additionally, the scheduled acquisition of the instruments from the vendor had a large impact on the selection of which buoys would obtain the sensors and when they would be deployed.

NDBC maintains a list of buoys with the sensors that are to be deployed. The lists provided by the Regional Associations are used in conjunction with NDBC priorities, the schedule of sensor delivery, and the maintenance schedule for the buoys to determine which sensors are to be added to buoys and when the additions should be made. The deployment schedule of buoys with specific sensors is derived from this list.

### III. PROCESS

The Gulf of Maine Ocean Observing System (GOMOOS) provided a list of proposed buoys for directional waves, ADCP, and salinity and then an update to the list was provided about six months later. The buoy at Jonesport, ME (44027) was proposed for all three parameters. The Georges Banks buoy (44011) was selected for directional waves and Nantucket (44018) was selected for salinity and ADCP additions. A request for salinity at the buoys at Georges Bank (44011) and East of Portsmouth, NH (44005) was also made. In November 2005, a request was made for directional wave, salinity, and ADCP as well as additional parameters at the Boston buoy (44013).

The Mid-Atlantic Coastal Ocean Observations Regional Association (MACOORA) was composed of representatives from New Jersey, New York, and Connecticut at the time of their submission of requirements. Virginia and Maryland inputs have not been received at the date of this

report. Directional waves were requested at Long Island (44009) and at Ambrose Light CMAN Station (ALSN6). ADCP and salinity data were also requested at Ambrose Light. In July 2006, an Acoustic Wave and Current (AWAC) sensor was installed at Ambrose Light. As of late July 2006, the current and wave data are under evaluation.

The South East Coastal Ocean Observation Regional Association (SECOORA) provided a list of requests. The highest priority location for the acquisition of directional wave data was the Edisto buoy (41004) and the West Tampa buoy (42036). At second priority were the St. Augustine buoy (41012), which is funded of the NOAA Coastal Storms Program), the Gray's Reef buoy (41008), which is funded by Gray's Reef National Sanctuary, and the Mobile buoy (42040). ADCP support was requested at the Edisto, West Tampa, Pensacola (42039), and Mobile buoys. The buoys at Frying Pan Shoals (41013), Diamond Shoals (41025), Edisto, and West Tampa were suggested for salinity sensors.

The Gulf of Mexico Coastal Ocean Observing System (GCOOS) provided a list to NDBC, that included directional waves on the Freeport, TX (42020) and, Galveston, TX (42035) buoys. Two buoys previously funded by the Minerals Management Service were also suggested, but they are no longer in service. ADCP and salinity sensors were requested for most of the buoys in the Gulf of Mexico.

The Southern California Coastal Ocean Observing System (SCCOOS) requested ADCP and salinity at Point Arguella (46023) or Santa Maria (46011) buoy, Point Conception (46063) or Santa Barbara (46054) buoy, and the Santa Barbara East buoy (46053), Santa Monica Basin (46025), South Santa Rosa Island (46069), and San Clemente Basin (46086) buoys.

The Central and Northern California Ocean Observing System (CENCOOS) provided a list of directional wave, ADCP, and salinity requests. Directional waves sensors are requested on the Cape Saint Martin (46028), Point Arena (46014), Santa Maria (46011), and Monterey Bay (46042) buoys. The Bodega Bay (46013), Santa Maria (46011), Cape Saint Martin (46028), and Point Arena buoys were suggested as sites for salinity and ADCP augmentation. The buoy at Santa Maria (46011) already has a working ADCP and data are being displayed on the NDBC website.

The Northwest Association of Networked Ocean Observing Systems (NANOOS) requested additional directional wave measurements at Stonewall Banks (46050), Port Orford (46015), Cape Elizabeth (46014), and Neah Bay (46087) and Hein Bank (46088). The top priority for directional waves was to keep the directional wave capability at the Columbia River Bar (46029). ADCP and salinity were prioritized as Columbia River Bar (46029), Neah Bay (46087), Stonewall Banks (46050), Port Orford (46015), Hein Bank (46088) and Cape Elizabeth (46041).

The Alaska Ocean Observing System (AOOS) did not address the issue of directional waves because of their understanding of the difficulty in acquiring them from the 6 meter NOMAD buoy. The hull shape precludes an accurate measure of waves. Although AOOS would like to have ADCPs and salinity collected at all Alaska buoys, priorities were Cape Suckling (46082), Fairweather Grounds (46083), and Cape Edgecumbe (46084).

Because there are so few buoys in the Caribbean region, they requested new buoys north and south of Puerto Rico. The Pacific Integrated Ocean Observing System (PacIOOS) group requested directional waves at 51001 and at 51002. Salinity and ADCP supplements were less important, but desired.

The Great Lakes Observing System (GLOS) also participated in the survey. Because the Great Lakes are freshwater, there is no salinity requirement. ADCPs were requested for the Lake Ontario Central (45012), Lake Michigan North (45002), Lake Michigan South (45007), Lake Huron North (45003), Lake Huron South (45008), and Lake Erie West (45005) buoys. The Lake Superior West (45006) buoy was a lower priority for the ADCP. Directional wave sensors, which are currently deployed on four of the buoys, are requested for the remaining five buoys in the region.

#### IV. RESULTS

With the ConWxB funding, NDBC will be able to augment the current suite of buoys with additional ocean sensors. Surface salinity sensors will be on 46 buoys and twelve buoys will support CT strings with varying numbers of CTs at depths based on regional observing schemes. A total of 47 ADCPs will collect current profile data from buoys and the remaining 54 buoys will be equipped with surface current meters. All buoys except the 25 3 meter NOMADs will be augmented with directional waves.

Not all of the requests provided by the regional associations can be fulfilled, because the requests far exceed the number of sensors that can be provided with the available funding. The plan for visiting the existing NDBC buoys has been studied to determine which of the requested buoy augmentations can be accomplished within the period to put out the most sensors. The delivery schedule of the instruments can also play a role in what sensors are deployed on specific buoys.

Twelve ADCPs are currently deployed on NDBC buoys, satisfying some Regional Association requests. ADCPs have been deployed at 46011, 46023, 46063, 46054, 42036 and 41036. The first four were requests by SCCOOS and all four have had working ADCPs during the past few years. Upgrades will bring them all back on-line. The next to last was in response to SECOORA and GCOOS requests and

was deployed in April 2006. The ADCP at 41036 was partially funded by the US Marine Corps and the University of North Carolina at Wilmington and is currently providing data. Transmitting the data to NDBC over Iridium provides data required to implement quality control algorithms for ADCP data. The experience gained from the Minerals Management Service project to acquire and quality control approximately 45 oil company ADCPs (3 to 6 times per hour) will lead to implementation of a similar quality control system for NDBC and IOOS partner ADCP data.

Surface CT sensors are deployed in the bridle of some buoys and in conjunction with ADCPs in cages below the bridle on other buoys. Because of the sensitivity of CT sensors to the environment, initial CTs are being deployed on buoys near shore. Once more experience has been gained, the program will be accelerated and deployment completed within two years. Except for three prototype buoys in the Gulf of Mexico, no CT strings have been deployed yet, but plans are underway to deploy the twelve strings of CTs over the next two years on three meter discus buoys. The current plan is for three CT strings in the Gulf of Mexico, five on the East Coast, and four on the West Coast.

Directional wave capability is currently available at 28 of the NOOS buoys. Eight of the buoys measure directional waves using a heave, pitch, and roll sensor and the other twenty use angular rate sensors (ARS). An additional 37 discus buoys will be equipped with the ARS to acquire directional waves.

Specific locations for the buoys to be upgraded with ocean sensors by ConWxB will be available in early autumn 2007. Schedules for available Coast Guard vessels used to deploy and retrieve buoys, unanticipated failure of buoys, sensors, and moorings, and environmental events may cause the schedules to change. Updates to the schedule will be provided periodically.

#### V. CONCLUSION

Through an increase in funding for ConWxB, NDBC will increase the number of ocean sensors on NOOS buoys over the next two years. Additional current profiles, surface salinity, temperature and salinity with depth, and directional waves will be collected with the expansion. The additional sensors will increase the amount of oceanographic information available to IOOS partners and the science and monitoring community worldwide. The data are provided at least once per hour and displayed on the NDBC website, distributed over the Global Telecommunications System to forecasters and modelers around the world, and available on NDBC's IOOS Data Management and Communications (DMAC) real-time OPENDap Server.